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STATISTICAL ANALYSIS OF INTERNAL PARAMETERS OF RADIATING SYSTEMS WITH REACTANCE ELEMENTS

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ABSTRACT

The mathematical model of the statistical analysis of a standing-wave ratio of a voltage on an input of the radiator is offered depending on small random fluctuations of values of reactive elements, included into the radiator and from coordinates of their inclusion. From the results of a statistical estimation it follows, that minor random deviations of parameters of reactive loads of the short vibrators from design values result in essential changes of a standing-wave ratio, that must be taken into consideration at designing and using of similar radiating systems

One of the important internal radio parameters of radiating systems (RS) with impedance elements is the standing-wave ratio of voltage (K_s) on input connectors RS, which as is known is expressed through active (R_{in}) and reactive (X_{in}) components of input impedance at given frequency as follows [1]:

$$K_s = \left\{ 1 + \sqrt{1 - 4R_{in}^n \left[(1 + R_{in}^n)^2 + X_{in}^{n^2} \right]} \right\} : \left\{ 1 - \sqrt{1 - 4R_{in}^n \left[(1 + R_{in}^n)^2 + X_{in}^{n^2} \right]} \right\},$$

(1)

where R_{in}^n , X_{in}^n are normalized on a wave impedance of a feeding channel (W_{fd}) components of input resistance of a radiating system.

In their turn components R_{in}^n and X_{in}^n are functions of values (x_i) of geometrical parameters RS (d, r_a), included in it of impedances (Z) and coordinates of their inclusion (h_Z), operational frequency (f) of an exciting source U, wave impedance W_{fd} etc (see fig.1). These relations can be presented as:

$$R_{in}^n = R(x_1, x_2, ..., x_N) = R(x_i), \quad i = 1, 2, ..., N;$$

$$X_{in}^n = X(x_1, x_2, ..., x_N) = X(x_i), \quad i = 1, 2, ..., N;$$

(2)

Taking into account, that R_{in}^n, X_{in}^n, x_i are random quantities and regarding systematic components of errors of values R_{in}^n, X_{in}^n and parameters x_i, which can be defined and

eliminated, we consider expressions (2) with the account of only random errors (Δ_{x_i}), the estimation of which is fulfilled below.

Let's expansion (2) in a Taylor's series near to average values of x_i or their mathematical expectations [2]:

$$R_{in}^n + \Delta_{R_{in}^n} = R(x_i) + \sum_{i=1}^N \frac{\partial R_{in}^n}{\partial x_i} \Delta_{x_i} + \frac{1}{2} \sum_{i=1}^N \frac{\partial^2 R_{in}^n}{\partial x_i^2} \Delta_{x_i}^2 + \ldots;$$

$$X_{in}^n + \Delta_{X_{in}^n} = X(x_i) + \sum_{i=1}^N \frac{\partial X_{in}^n}{\partial x_i} \Delta_{x_i} + \frac{1}{2} \sum_{i=1}^N \frac{\partial^2 X_{in}^n}{\partial x_i^2} \Delta_{x_i}^2 + \ldots. \quad (3)$$

Provided that the random errors Δ_{x_i} are small in comparison with values x_i we neglect addends containing hjwers of Δ_{x_i} above the first. Further, subtracting (2) from (3) we receive values of random errors as:

$$\Delta_{R_{in}^n} = \sum_{i=1}^N \frac{\partial R_{in}^n}{\partial x_i} \Delta_{x_i}; \quad \Delta_{X_{in}^n} = \sum_{i=1}^N \frac{\partial X_{in}^n}{\partial x_i} \Delta_{x_i}. \quad (4)$$

Powering both parts of expressions (4) in a square and taking into account absence of a correlation between parameters x_i, we determine dispersions of components R_{in}^n and X_{in}^n:

$$\sigma^2(R_{in}^n) = \sum_{i=1}^N \left(\frac{\partial R_{in}^n}{\partial x_i}\right)^2 \sigma^2(x_i); \quad \sigma^2(X_{in}^n) = \sum_{i=1}^N \left(\frac{\partial X_{in}^n}{\partial x_i}\right)^2 \sigma^2(x_i). \quad (5)$$

At known dispersions (5) we determine a dispersion K_s, considering similarly to the previous making of expressions (5) provided that the random errors $\Delta_{R_{in}^n}$ and $\Delta_{X_{in}^n}$ are small in comparison with values of the relevant components R_{in}^n and X_{in}^n:

$$\sigma^2(K_s) = \left(\frac{\partial K_s}{\partial R_{in}^n} + \frac{\partial K_s}{\partial X_{in}^n}\right)^2 \cdot \sigma^2(R_{in}^n) \cdot \sigma^2(X_{in}^n). \quad (6)$$

Derivatives from K_s for expression (6) is determined from (1) as:

$$\frac{\partial K_s}{\partial R_{in}^n} = \frac{4\left(R_{in}^{n^2} - X_{in}^{n^2} - 1\right)}{\left[\left(1 + R_{in}^n\right)^2 + X_{in}^{n^2}\right]^2 \sqrt{1 - \frac{4R_{in}^n}{\left(1 + R_{in}^n\right)^2 + X_{in}^{n^2}}} \left[1 - \sqrt{1 - \frac{4R_{in}^n}{\left(1 + R_{in}^n\right)^2 + X_{in}^{n^2}}}\right]^2} \quad (7)$$

$$\frac{\partial K_s}{\partial X_{in}^n} = \frac{8 R_{in}^n X_{in}^n}{\left[\left(1 + R_{in}^n\right)^2 + X_{in}^{n^2}\right]^2 \left[1 - \frac{4 R_{in}^n}{\left(1 + R_{in}^n\right)^2 + X_{in}^{n^2}}\right] \left[1 - \left[1 - \frac{4 R_{in}^n}{\left(1 + R_{in}^n\right)^2 + X_{in}^{n^2}}\right]\right]^2}, \quad (8)$$

and dispersions of expressions R_{in}^n and X_{in}^n for the studied radiator we shall find from the formulas (5).

Thus, with the help of expressions (4) - (8) it is possible to design a statistical estimation any RS with included reactive elements. Thus, it is necessary to know particular relations such as (2) for R_{in}^n and X_{in}^n and derivatives from them on the conforming parameters x_i.

Let's put the results of a statistical estimation K_s on an input shortened twice ($d=0,12\lambda$) concerning resonant length of the symmetrical vibrator with included in radiating branches the inductive loads depending on random fluctuations of values of these loads and places of their connection (fig. 1). An estimation is designed by method with usage of the theory of an equivalent long line.
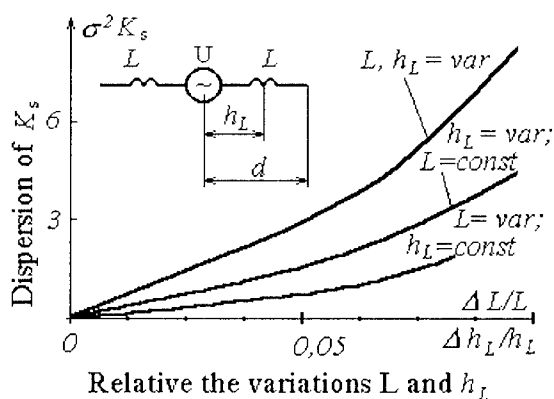

Fig.1. Dispersion K_s versus the random errors L and h_L

The results of research are shown in a fig. 1. As follows from the charts of a fig. 1 random changes of parameters of included reactances result in essential oscillations K_s.

For small-sized radiators of such type it is possible to explain this phenomenon by narrowing of their bandwidth because of linear shrinkage of length.

Let's mark, that in the not shortened radiators of a fluctuation of reactances. included for correction distribution of a current in them with the purpose, for example. dilating of frequency range or the correction of the directional diagrams do not result in such sharp of variations the input characteristics.

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